CONCEPT PAPER

TECHNICALLY ENHANCED NATURALLY OCCURRING RADIOACTIVE MATERIAL (TENORM) AND PHOSPHATE MINING IN WEST-CENTRAL FLORIDA

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Executive Summary

This concept paper was prepared at the request of the Regional Administrator of the United States Environmental Protection Agency (EPA), Region 4, to aid in the understanding of a potentially significant environmental issue in the State of Florida relating to the redevelopment of formerly mined phosphate lands. The phosphate mining industry is one of the primary suppliers of phosphate rock in the United States (US) and one of the largest industry contributors to the Florida economy.

Although phosphate ore mined and processed in Florida provides the bulk of material for the production of fertilizers in the United States, and thereby is a critical component of the American agricultural industry, the phosphate industry also has many environmental challenges. This concept paper addresses one significant environmental challenge resulting from the mining and processing of phosphate ore, which is the presence of Technically Enhanced Naturally Occurring Radioactive Materials (TENORM).

During the mining and processing of phosphate ore, Radium ^{226} (Ra^{226}), a naturally occurring radioactive isotope, is excavated with the phosphate ore and distributed at the land surface in the mining spoils and process wastes. After an area has been mined, the land is reclaimed to varying degrees and used for a variety of purposes, including agricultural, industrial, commercial, and residential. Because these processes can leave elevated levels of radiation from Ra^{226} in the soil, it can present an increased long-term occurrence of cancer risks, particularly where residential properties are concerned.

Radiation measurements in residential areas overlying formerly mined phosphate land indicate the possibility of long-term cancer risks in the range of 10^{-2} to 10^{-3}, well outside EPA's acceptable risk range of 10^{-4} to 10^{-6}. Presently, approximately 11 square miles (mi^2) of formerly mined land have been developed for residential purposes, resulting potential exposures to a population of approximately 42,000 people. An additional 215 mi^2 of land have been mined but not developed.

This paper analyzes the phosphate mine and legacy areas in Florida utilizing the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980 framework for ensuring protectiveness. However, this paper does not presume that a CERCLA response is the appropriate vehicle or the sole means of ensuring protectiveness. There are no relevant state regulations that would protect the public from elevated levels of radiation associated with phosphate mining activities from an on-going operational perspective. For example all or a portion of the area could be addressed as a State voluntary action. This paper focuses on CERCLA, because it provides a recognized paradigm for establishing protective levels and response actions from the Federal-EPA perspective.

Under CERCLA, response actions must be protective of human health (i.e., excess life-time cancer risks within 10^{-4} to 10^{-6}) and must comply with Applicable or Relevant and Appropriate Requirements (ARARs). As a result, EPA has applied soil criterion for Ra^{226} of 5 pico curries per gram (pCi/g) above background as an ARAR in the cleanup of Ra^{226}-contaminated Superfund sites throughout the country. ATSDR has indicated that, if consulted, it would likely agree that the 5 pCi/g above background criterion is protective of human health.

The selection of an appropriate criterion for the assessment and potential cleanup of these formerly-mined phosphate areas is greatly complicated by the widespread nature of the radium contamination. Cleanup of developed areas can be accomplished but at significant expense. Substantial efforts are being made to work with the State and ATSDR to develop an assessment and cleanup criterion that is not only protective of human health, but that is cost-effective and balances the degree of risk with other socio-economic impacts.

Statement of Confidentiality and Disclaimer

This document is confidential and is not subject to release pursuant to the Freedom of Information Act. This document is part of an internal deliberative process. It is intended to aid the United States Environmental Protection Agency (EPA) in the consideration of phosphate mining and related issues in the State of Florida. It is not intended to provide an Agency determination nor endorsement of any approach, nor does it draw any formal conclusions.

Acknowledgments

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Valued in-sight into the Agency for Toxic Substance and Disease Registry's public health protection process and criteria were provided by William Cibulas, Jr., Ph.D., Acting Director, Division of Health Assessment and Consultation; Michael Brooks, Ph.D., Division of Health Assessment and Consultation; and Carl Blair, Region 4 Coordinator, Division of Regional Operations.

1.0 Purpose of Concept Paper

This concept paper was prepared at the request of the Regional Administrator of the United States Environmental Protection Agency (EPA), Region 4, to aid in the understanding of the various criteria and approaches used by EPA and other federal agencies, States, and other organizations in the assessment, public health protection, and cleanup of radiological contamination from Radium ^{226} (Ra^{226}) in soil. This paper is further intended to support EPA's and ATSDR's efforts to develop a strategy to address potential current and future impacts to human health posed by Ra^{226} from phosphate mining activities in west-central Florida.

A by-product from the mining of phosphate ore is the contamination of large areas of soil with Ra^{226}. This isotope is a naturally-occurring element in the underlying phosphate matrix that normally poses no risk to human health due to its location in the subsurface. However, during the course of the mining, the phosphate ore is brought to the ground-surface. Remnants of the ore are left at the surface or placed in large open storage areas at the surface. Data indicate that due to the mining and processing of the phosphate ore, Ra^{226} is present in these areas at levels that could pose an unacceptable level of long-term carcinogenic risk levels to the public. There are no Ra^{226} contaminated areas that could cause any acute radiation health effects. Historically, these formerly mined lands have been popular areas for residential development. If Ra^{226} was not addressed prior to the development of these lands, residents may be exposed to increased levels of radiation, and unacceptable long-term increases in carcinogenic risk.

A primary consideration in developing an approach to protect human health from increased radiation exposure is the selection of a criterion for the assessment and cleanup of Ra^{226}-contaminated soils. Because a review of federal and state environmental laws indicates that the most appropriate might be to conduct a cleanup using an approach similar to the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), this paper has focused its review on criteria established under, CERCLA, the National Contingency Plan (NCP), and EPA Superfund Guidance, along with criteria established by ATSDR and the State of Florida.

Based on a review of all available criteria used by EPA, ATSDR, and other federal agencies, the State of Florida, and scientific organizations, this concept paper proposes a criterion, as well as various alternatives, for addressing the increased radiation risks. These approaches include protective measures that take into account the timing of response actions relative to the degree of development, while acknowledging a need to balance socio-economic considerations with the degree of protectiveness.

2.0 Technically Enhanced Naturally Occurring Radioactive Material (TENORM)

Technically Enhanced Naturally Occurring Radioactive Material (TENORM) is a by-product of the extraction or processing of naturally-occurring materials with radionuclides, such as Ra^{226} , that are exposed to environmental media such as soil, water or other natural material. Exposure to TENORM with elevated levels of radionuclides results in increased levels of radiation exposure and correspondingly greater long-term risks of contracting cancer.

With respect to phosphate mining in west-central Florida, TENORM is generated from the extraction and processing of phosphate ore with radionuclides including uranium and radium. During the mining, refining, and processing of the ore, surface soils in the vicinity of these areas are contaminated with Ra^{226} above background levels. Although uranium is present in the ore, the uranium typically remains bound with the phosphate. TENORM contamination may also occur in groundwater and surface water; however, data suggest that the contamination of these media is not as widespread as the soil contamination.

EPA's OSWER Directive 9200.4-25 provides guidelines for addressing radiation risks associated with TENORM in the same manner as other sources of radiation and non-radioactive chemicals. A review of ATSDR's guidance indicates that it would evaluate the potential for increases in adverse health effects based on minimum risk levels for radiation. While the State of Florida recognizes the occurrence of TENORM, no formal criteria have been developed to address long-term carcinogenic risks from TENORM exposures.

3.0 Background on Phosphate Mining in Florida

Phosphate mining in Florida dates back to the late 1800's. Phosphate mined in west-central Florida provides the bulk of phosphate used in the United States. Much of the phosphate is processed at local chemical plants and converted to phosphoric acid. The majority of this raw material is used in the production of fertilizer, but phosphoric acid also has a wide variety of other uses in the food, chemical, and other industries.

The phosphate industry in Florida is one of the largest industries in the State. It provides 75% of the nations phosphate supply and 25% of the world's supply. During 2003, approximately 4,500 acres of land were mined, producing 23 million metric tons of phosphate. Total industry gross profits in 2005 for the three operating companies were approximately $2 billion.

Phosphate mining began with the collection of phosphate pebbles from rivers such as the Peace River, in Florida, but later evolved in the early 1900's to the current process of strip-mining. Strip-mining in this area basically involves the removal of the soil overburden to expose the underlying matirx of phosphate ore, sand and clay. This matrix is typically located at a depth between 15 to 30-feet below land surface. Early mining continued to rely on the removal of soil with visible portions of phosphate ore. In the 1930's, however, a process known as flotation was developed that was able to recover much smaller particles of phosphate ore that would have normally been discarded with the sand and clay portions of the matrix.

Phosphate mining has been conducted extensively in Polk and Hillsborough Counties, but is expanding southward into Hardee, Manatee, Sarasota, and DeSoto counties. Figure 1 depicts the location and aerial extent of the phosphate deposit estimated to contain mineable amounts of phosphate. This area is commonly referred to as the "Phosphate Belt". It is estimated to cover an area approximately 2,150 square-miles (mi^2) in size.

In addition to the potential human health risk from TENORM, there are numerous other environmental issues associated with the phosphate mining industry that are being evaluated by EPA and the State of Florida. The processing of the phosphate ore and separation of the phosphate rock from the sand and clay matrix require enormous quantities of water. Large areas of land are also required for the long-term storage and disposal of the sand tailing and clay-slurries. The conversion of the phosphate rock to phosphoric acid results in the production of a by-product referred to as phosphogypsum. The phosphogypsum is primarily calcium sulfate, but it is contaminated with TENORM and has no current acceptable use. This material is currently being stored at multiple locations in large above-ground stacks known as gypsum or "gyp" stacks. Rainfall percolating though the gypsum stacks results in the generation of acidic wastewater that must be managed. Due to the expansive nature of the mines, processing areas and chemical plants they frequently overly, at least in-part, the watershed of ecologically significant wetlands and rivers. Potential environmental impacts from phosphate mining in Florida is an important topic among state regulators, elected officials, local communities, and environmental organizations.

3.1 Mineable Area

The extent of the phosphate mineable limit is approximately 2,150 mi^2. Within this mineable limit, areas can generally be placed into one of three categories with correspondingly different exposure pathways, degrees of risk, and protective measures. A description of these areas is presented below, and outlined in Figure 2.

- Approximately 11 mi^2 of mined land has been developed for residential use. Human health risks result from potential current and future exposures to TENORM. These exposures include the inhalation of radon gas (a degradation product of Ra^{226}), direct exposures to radiation, or ingestion of radium-contaminated soils. Conventional cleanup alternatives would likely be required to limit exposures and reduce risks to residents occupying homes overlying radium-contaminated soils.

- Approximately 215 mi^2 of land has been mined, but not yet developed. Human health risks in these areas are limited to those in reclaimed and partially developed areas, but because broad development has not occurred, a wider range of protective measures may be available. If an area is known to be contaminated, the type of use could essentially determine the type of response that is needed to protect human health. If

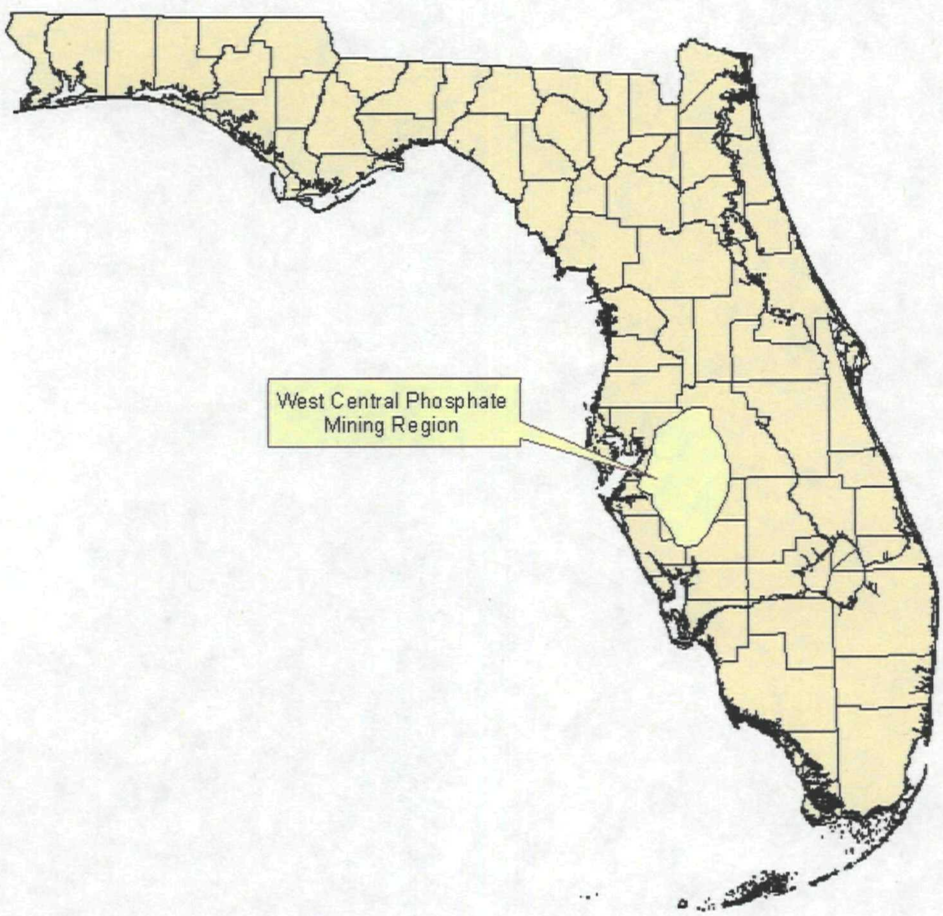

Figure 1
Location Map of Florida Phosphate

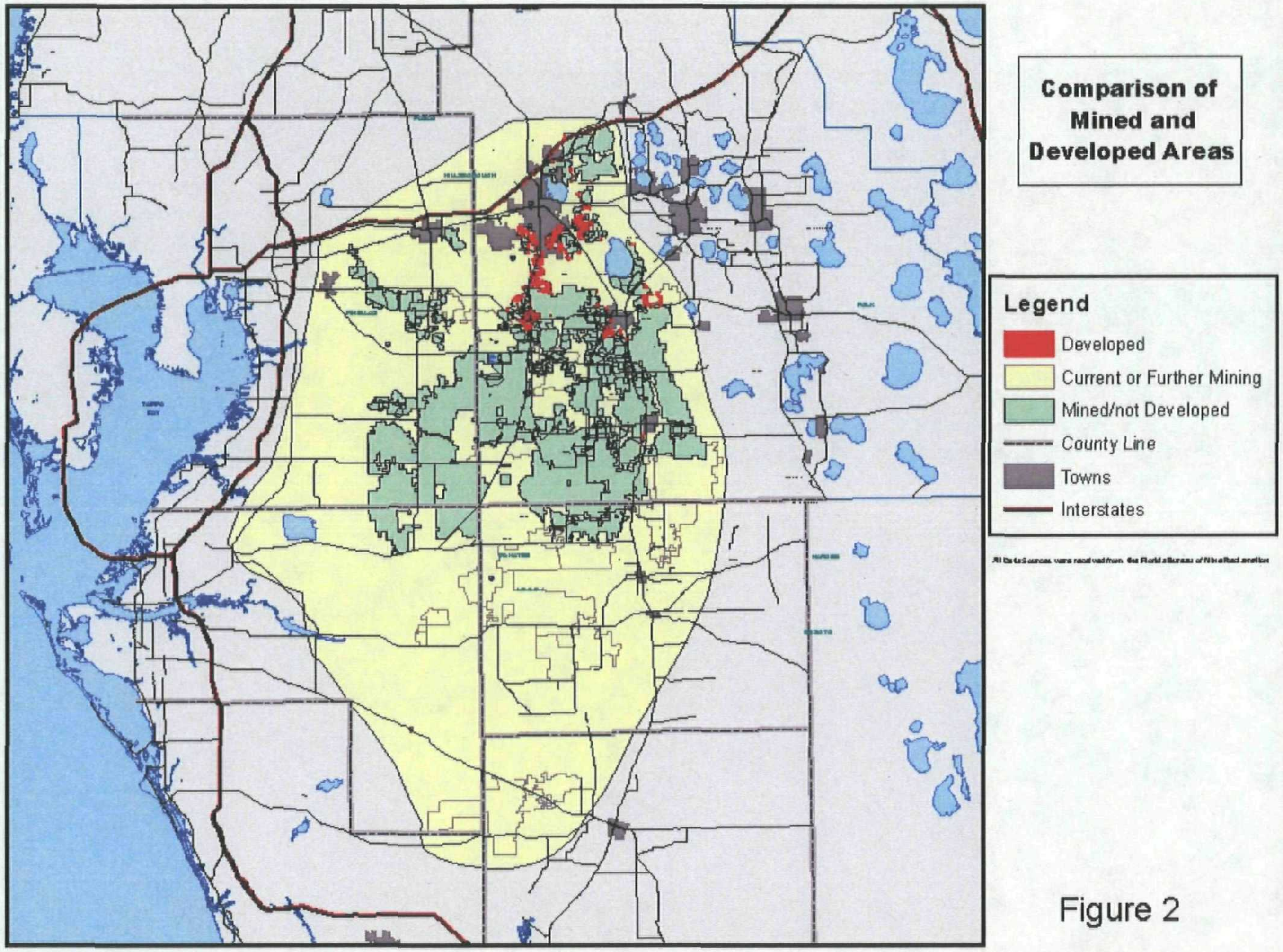
Comparison of
Mined and
Developed Areas
Legend
Developed
Current or Further Mining
Mined/not Developed
County Line
Towns
Interstates

Figure 2

the area was desirable for residential development, potential risks from exposure to radium-contaminated soil could be addressed through a variety of engineering alternatives that involve the removal or shielding of the contaminated soil. Alternatively, potential risks to human health could be managed through zoning restrictions that control the use in a way such that the exposure frequency is compatible with the level of contamination.

- Approximately 1,924 mi^2 is either currently being mined or could be mined in the future. Any potential risk that might occur would be from the development of the property at some point in the future; therefore, the greatest flexibility exists in developing measures that would be protective of human health in these areas. In addition to the measures described above, it may be feasible to modify the mining and waste material handling methods such that it reduces the amount and extent of Ra^{266} left at and near the ground surface.

3.2 Exposure Pathways

Based on the review of currently available data, it appears that all media can be impacted by phosphate mining processes. Exposures to radon gas, a decay-product of Ra^{226}, can occur through inhalation while exposures to Ra^{226} can occur through ingestion of contaminated soil and water. Direct exposures to gamma radiation can also occur. The greatest potential for exposure is expected to be associated with individuals occupying dwellings that are located over formerly mined land that never under-went any formal state reclamation. This exposure is expected to occur from inhalation of radon gas accumulating in the dwelling and from gamma radiation accumulating in the underlying soil and penetrating the foundation. Ingestion of Ra^{226}-contaminated soil and direct exposure to gamma radiation are primary routes of exposure outside the dwelling. A final route of exposure could be the ingestion of Ra^{226}-contaminated water.

3.3 Potentially Affected Population

Potential risks to human health from exposures to Ra^{226} due to phosphate mining can be categorized into current and future exposures. Each category has its own unique technical, socio-economic, and regulatory considerations. A fundamental difference in responding to these exposures is the type and timing of protective measures that can be employed. Areas currently occupied will require a more timely, aggressive response, whereas areas that are not currently developed may be addressed by less expensive institutional controls.

A review of the residential tax parcel information for Polk County, Florida, indicates that approximately 11 mi^2 (i.e., 7,000 acres) of formerly mined phosphate land have been developed for residential use. Based on a conversion factor of two homes per acre and three occupants per home, a population size of 42,000 could currently be exposed to TENORM from former mining operations.

Data collected by EPA in 1988 from the Borden Chemical/Tenoroc Mine Site and data collected by the Florida Department of Health (FDOH) from early 1979 to the late 1990s, provided EPA with insight regarding the potential for increased levels of radiation exposure for current and future residents living over formerly mined land. Monitoring conducted by FDOH included several thousand measurements of gamma radiation levels, Ra^{226} concentrations in soil, and radon gas levels in homes from 170 different parcels of land. This data indicated that forty percent of the parcels surveyed had gamma radiation levels above the 20 micro rotens per hour (µr/hr) screening level currently being considered by EPA. As a tool to aid EPA in the initial identification of an area that could be impacted by TENORM, the indoor gamma radiation level of 20 µr/hr from 40 CFR 192 was considered as a screening level. Thirty percent of the parcels had gamma radiation levels that ranged from 50 to 70 µr/hr, which is approximately equivalent to a dose of 300 to 420 millirems per year (mRem/yr) or an excess cancer risk level between 6×10^{-3} to 8.8×10^{-3}.

Data from the initial investigation of the Borden Chemical/Tenoroc Mine Site indicated the presence of elevated levels of gamma radiation at all of the fifty one locations measured. A summary of the distribution of the measurements follows, along with the corresponding risk:

- 100% of the gamma radiation measurements exceeded 15 mRem/yr. This dose level has been cited as a "rule-of-thumb" for an acceptable dose level for cleanup under Superfund since it is approximately equivalent to an excess long-term cancer risk of 3×10^{-4}, which is near the upper end of the 10^{-4} to 10^{-6} CERCLA risk range. Please note that Superfund uses risk or ARARs, not mRem/yr, for cleanup levels.

- 55% of the gamma radiation measurements exceeded 100 mRem/yr. This dose is approximately equivalent to an excess long-term cancer risk of 2×10^{-3}. This is also the same as the minimum risk level identified by ATSDR as an acceptable level of protectiveness.

- 18% of the gamma radiation measurements exceeded 500 mRem/yr. This dose is approximately equivalent to an excess long-term cancer risk of 1×10^{-2}. This is also the same level proposed by FDOH as a guidance threshold for undertaking cleanup actions.

3.4 GAO and OIG Reports

In November 1988, the General Accounting Office (GAO) published a report to Congress, entitled "Hazardous Waste, Unaddressed Risks at Many Potential Superfund Sites, GAO/RCED-99-8." The study was intended to investigate the reason for the backlog of sites in EPA's Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) database that are categorized as having "unaddressed risk," but for which there has not been significant progress.

In 1999, as a result of the GAO report, the South Site Management Branch (SSMB), Waste Management Division, Region 4, undertook a review of its inventory of sites reported as having "unaddressed risks." The SSMB discovered that a significant number of these sites were related to the phosphate mining industry in Florida. A review of the CERCLIS database indicated that there are 21 phosphate mining sites presently in CERCLIS.

A summary of these sites is provided in Appendix A. The majority of the sites were discovered in 1979 and 1980. Preliminary Assessments were completed on the majority of the sites by the State of Florida during the early to mid 1980s. EPA conducted Site Inspections on most of the sites in the late 1980s and early 1990s. Site Inspection Prioritizations were conducted by EPA for most of the sites in the mid 1990s. Many of these sites were evaluated using the Hazard Ranking System (HRS) and had preliminary scores higher than the 28.50 threshold, even though none of the preliminary scores factored into the evaluation the radiological contamination.

In March 2004, the EPA Office of Inspector General (OIG) published an evaluation report, entitled "Nationwide Identification of Hardrock Mining Sites, Report No. 2004-P-00005." This review was conducted as part of the OIG's review of the financial impact of "mega-sites" on the Superfund Trust fund. The phrase "mega-site" has been coined to identify sites that are projected to exceed $50 million in cleanup costs. A fundamental question in this review was "Is there a financial impact from hardrock mining sites on the Trust Fund and on State?" Among other things, the report noted that the phosphate mining sites in Region 4, if addressed through the NPL as mega-sites, represent about 50% of the future budget needs for future cleanup costs of these CERCLIS sites (i.e., $11 billion out of the $24 billion projected for future cleanup costs of mega-sites).

4.0 Agencies/Organizations and Radiation Risks

Table 1 provides a detailed summary of primary federal and state Ra^{226} remediation criteria used for the protection of public health from TENORM exposures and for the assessment and cleanup of soil contaminated with Ra^{226} in residential areas. This table does not address criteria developed for non-TENORM exposures, such as radiation from medical or research facility sources, nuclear power plants, radioactive waste disposal facilities, or terrorist events.

In addition, criteria used by federal governmental agencies, such as the Department of Homeland Security (DHS), are not included in this table.

Table 1 - Comparison of TENORM Criteria for the Protection of Public Health					
Agency/State	Criteria				Notes
	Dose (mRem/yr)	Exposure Rate (μR/hr)	Ra^{226} - Soil (pCi/g)	Corresponding Superfund Risk Equivalent of Ra^{226} Concentration	
Federal Agencies					
EPA, OSWER Dir. 9200.4-25 (1997)	–	–	5	10^{-4} to 10^{-6}	OSWER's over-riding criteria is compliance with the CERCLA risk range. Uranium Mill Tailings Radiation Control Act (UMTRCA) is routinely applied as an ARAR. UMTRCA standard is 5 pCi/g from surface to 15 cm below surface; 15 pCi/g for each increment of 15 cm below surface. OSWER Directive explains how subsurface level of 15 pCi/g is ARAR only when it will get to 5 pCi/g. The 5 pCi/g concentration is also routinely used by Superfund's removal program as a cleanup value, and is a benchmark for NPL listing.

Table 1 (Continued)					
EPA, ORIA (Draft Federal Guidance - 2005) (UMTRCA - 1978)	100 (all sources) 15 (high-level sources)	20	5	–	Source: Draft National Guidance for the Protection of the Public proposed a national protection guideline of 100 mRem/yr for all sources. 40 CFR 192 (UMTRCA) provides criteria for the cleanup of Radium contaminated soil of 5 pCi/g at the surface and an indoor gamma radiation level of 20 μR/hr for radon gas protection. ORIA has proposed a dose level of 15 mRem/yr for high level (i.e., transuranic waste) waste disposal areas, such as Yucca Mountain.
State Agencies					
Florida, FAC 64E-5.1001 (1989)	–	20	–	–	FAC establishes the 20 μR/hr (including background) as an indoor criterion for the protection against radon gas exposure. The State has advised that this criterion has only been used as a guidance value.
Alabama (mid-1990s)	–	50	5	–	Regulates TENORM if the source exceeds 50 μR/hr (including background) or Ra exceeds 5 pCi/g.

Table 1 (Continued)					
Georgia (mid-1990s)	–	50	30/5	–	Radon gas < 20 pCi/m^2 /s - 30 pCi/g; Radon gas ≥ 20 pCi/m^2 /s - 5 pCi/g
Mississippi (mid-1990s)	–	50	30/5	–	Same as GA
South Carolina (mid-1990s)	–	50	30/5	–	Same as GA and MS
Louisiana (mid-1990s)		50	5/15/30	–	5 pCi/g for upper 15cm; 15 pCi/g below 15 cm; 30 pCi/g below 15 cm, if the dose does not exceed 100 mRem/yr.
Texas (mid-1990s)	–	50	30/5	–	Same as GA, MS and SC
Scientific Organizations					
ICRP Report No.60, Principals for Limiting Exposure to the Public to Natural Resources of Radiation (1990)	100/500	–	–	–	ICRP recommends limiting doses to 100 mRem/yr for repeated exposure over prolonged periods, and 500 mRem/yr for any year.

Table 1 (Continued)					
NCRP - General Population, NCRP Report No. 116 (1993)	100/500	–	–	10^{-4} or less (As-Low-As-Reasonably-Achievable) (ALARA)	NCRP recommends that radiation protection for the general public should be comparable to or less than those in safe industries; radiation protection for the public should result in an average annual cancer risk of 10^{-4} or less. NCRP recommends that doses be limited to 100 mRem/y for continuous exposure and 500 mRem/yr for infrequent exposure. NCRP also recommends incorporating ALARA to balance societal needs and cost with protection of public health.
CRCPD, *Conference of* Radiation Control Program Directors - Implementation Guidance for Regulation and Licensing of Technology TENORM, Part N of the Suggested State Regulations for Control of Radiation (2004)	100	–	5	–	CRCPD *provides radiation guidelines to* States. Incorporation of guidelines is voluntary. 100 mRem/yr is applied as an exemption level for which releases below this level do not require permitting or regulation under state radiation control laws.

On January 3, 2006, DHS proposed "Protective Action Guides" (PAGs) that are designed to support actions necessary to protect public health in response to a terroristic event, such as the detonation of a Radiological Dispersal Device (RDD) or an Improvised Nuclear Device (IND). The DHS guidelines mainly establishes PAGs that protect the public from high doses of radiation during the early and intermediate stages of a response to a RDD or IND. No criteria are specified for the later phase of response activity that would address long-term cleanup and protectiveness issues. Furthermore, the DHS guidance specifically states that it is not intended for use at site cleanups occurring under other statutory authorities, such as CERCLA, NRC's decommissioning program, or other federal or state cleanup programs.

4.1 Federal Agencies

EPA's approach to addressing radiological contamination under Superfund is presented in OSWER Directives, *"Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination,"* OSWER No. 9200.4-18, August 22, 1997 and *"Use of Soil Cleanup Criteria in 40 CFR Part 192 as Remedial Goals for CERCLA Sites,"* OSWER No. 9200.4-25, February 12, 1998 (Attachment A). As with chemical contaminants, remedies intended to address risks from radioactive materials must always comply with the CERCLA carcinogenic risk range of 10^{-4} to 10^{-6}, as established in the NCP, and in compliance with ARARs. The primary ARAR in this case, and with other radium-contaminated Superfund sites, is the Uranium Mill Tailings Radiation Control Act (UMTRCA) (40 CFR 192). UMTRCA establishes remediation levels of 5pCi/g above background for Ra^{226} in soil, and 20 μR/hr above background for indoor gamma radiation exposures. OSWER guidance identifies an annual dose of 15 mRem/yr as being approximately equivalent to a risk level of 10^{-4}. This dose level, however, is not a promulgated criterion and cannot be used as a cleanup standard. UMTRCA regulations were promulgated in 1978 are managed through the EPA Office of Radiation and Indoor Air (ORIA). These regulations were originally promulgated to address mill tailings associated with uranium and thorium mining, but have since been applied in the cleanup of other radionuclides and radioactive sites.

ORIA developed draft Federal Guidance for the Protection of the Public (FGPP) in 2005 that was designed to establish minimum levels of protectiveness for the public from all radiation sources. Two risk optimization approaches are proposed in the FGPP. One approach replaces a 500 mRem/yr all source limit with an optimization approach for setting individual source limits. The second approach establishes a 100 mRem/yr dose level with an optimization approach for setting individual source limits. Neither option would affect how Superfund cleanup levels are selected. This Guidance is currently under review by OMB.

The Department of Defense (DOD) generally incorporates the provisions of UMTRCA in the cleanup of radium contaminated soils. UMTRCA's cleanup standard applies a concentration of 5 pCi/g, above background, for the cleanup of contamination located at the surface to a depth of 15 cm below surface and a concentration of 15 pCi/g for radium contamination below 15 cm.

The Department of Energy (DOE) Order 5400.5 incorporates the concept of "As-Low-As-Reasonably-Achievable" (ALARA) into its guidelines for the cleanup of radiation contaminated soil. ALARA balances risks from radiation exposure with other factors, such as cost and societal needs. From an implementation standpoint, however, DOE uses the criteria established by UMTRCA. Like DOD, DOE cleanup standards apply a concentration of 5 pCi/g above background for the cleanup of contamination located at the surface to a depth of 15 cm below surface, and a concentration of 15 pCi/g for radium contamination below 15 cm.

The Nuclear Regulatory Commission regulations for uranium mill tailing sites under 10 CFR Part 40 Appendix A, I, Criterion 6(6) also apply to radium and other radionuclides that are byproduct material, but these radionuclides and soil contamination are similar to TENORM sites. Criterion 6(6) requires that an estimate be made of the level of radiation, called a "benchmark dose," that an individual would receive after that site was cleaned up to the radium soil regulations under 40 CFR Part 192.12 (5 and 15 pCi/g of radium). This benchmark dose then becomes the maximum level of radiation that an individual may be exposed to from all radionuclides, except radon, in both the soil and buildings at the site. Thus, the radium concentration must be lower than 5 and 15 pCi/g to account for the presence of other radionuclides in the decay chain.

ATSDR has typically recommended an annual minimum risk level (MRL) of 100 mRem/yr. According to ATSDR, MRLs are not intended to address the potential for long-term increases in cancer risks, but are intended to address the potential for acute health effects to occur. According to the ATSDR, MRLs are intended to serve as screening levels to identify contaminants and potential health effects that may be of concern at hazardous waste sites. MRLs are not intended to address potential carcinogenic health effects, nor are they intended to define cleanup or action levels.

4.2 State Agencies

As shown in Table 1, most southern states have criteria promulgated to address potential risks from TENORM contamination. Most states have regulations that address TENORM, when radiation levels exceed 50 μR/hr. These states generally establish soil criteria for Ra^{226}. The criteria selected are generally related to either the depth of contamination or the amount of radiation being emitted. Soil criteria for Ra^{226} range from 5 to 30 pCi/g, above background.

The State of Florida has no enforceable criteria to address potential risks from radium. The Florida Department of Environmental Protection (FDEP) does not address radiological risks. In Florida, such risks are managed by FDOH. FDOH uses an exposure rate of 20 μR/hr, including background, as a guideline to evaluate potential indoor radon gas exposures. However, FDOH has advised EPA that it would propose a tiered approach for assessment and remediation of radiological contaminants in phosphate mining areas of 1) no action below a dose of 100 mRem/yr; 2) risk mitigation through education for dose levels from 100 to 500 mRem/yr; and 3) remedial measures for dose levels above 500 mRem/yr.

4.3 Organizations

Several science advisory boards have also developed and published recommendations for evaluating and addressing risks from exposure to TENORM. The International Council on Radiation Protection (ICRP) and the National Council on Radiation Protection (NCRP) both recommend annual dose limits of 100 mRem/yr for frequent exposures and
500 mRem/yr for infrequent exposures, or as an annual maximum limit.

The Conference of Radiation Control Program Directors (CRCPD), a body of state directors responsible for radiation control, recommends regulation of TENORM when levels exceed 100 mRem/yr. The CRCPD also recommends a soil remediation criterion of 5 pCi/g above background for Ra^{226}.

5.0 Conclusions

5.1 Summary for EPA, ATSDR and FDOH Criteria

Numerous discussions have occurred among EPA, ATSDR, and the State of Florida in an effort to reconcile the divergent points of view with respect to the risks to public health from exposures to TENORM. Pursuant to OSWER Directives, EPA's approach to evaluating radiation risks is the same as its risk-based approach to chemical carcinogens. This approach includes complying with ARARs and ensuring that remedies are protective of human health within a risk-range of 10^{-4} to 10^{-6}. The primary ARAR consistently used for Superfund cleanups of radium-contaminated soil is 5 pCi/g above background. A comparison of ARARs and risk levels among EPA, ATSDR, and the State of Florida is provided in Table 2.

Pursuant to CERCLA 104(i)(6)(F), ATSDR's role is to conduct "health assessments" that may be associated with "observable levels of exposure." In contrast, pursuant to 40 CFR § 300.430(d)(4), EPA is responsible for conducting a "site-specific baseline risk assessment to characterize the current and potential threats to human health and the environment." This creates two distinct roles for EPA and ATSDR, and therefore, the development of different criteria to address different potential health effects. For example, EPA has routinely used a soil cleanup criterion of 5 pCi/g in the cleanup of radium contaminated soils at Superfund sites. However, ATSDR has identified a threshold of 100 mRem/yr as a level, below which, the Agency would conclude that there should be no observable adverse health effects.

Table 2 Comparison of EPA, ATSDR, and State of Florida Dose and Ra^{226} To Relative Superfund Risk Levels				
Agency/State	**Annual Dose (mRem/yr)**	**Ra^{226} Soil Criteria (pCi/g)**	**Superfund Carcinogenic Risk Equivalent**	**Notes**
EPA, Superfund (40 CFR 192.12(a))	--	5 15	4×10^{-4} 1×10^{-3}	Criteria established under UMTRCA and used by Superfund as ARARs include 5 pCi/g for Ra^{226} in soil. Below a depth of 15 cm, 15 pCi/g is applied as the criterion in UMTRCA, but OSWER guidance requires that the 10^{-4} risk level still be met at depth.
ATSDR	-- -- 100	0.7 3.3 --	5×10^{-5} 3×10^{-4} 2×10^{-3}	ATSDR has established a minimum risk level of 100 mRem/yr for exposure to Ra^{226}. MRLs, however, are designed to only address non-carcinogenic health effects. Based on soil screening criteria from NCRP 129, and a dose level of 100 mRem/yr, a derived soil concentration for Ra^{226} would be 0.7 pCi/g. Using ATSDR's risk calculation methodology of including risk from radon gas with the gamma exposure, the 0.7 pCi/g soil criterion would result in an equivalent level of risk.
State of Florida	500 100	85 17	7×10^{-3} 1×10^{-3}	Using EPA's risk calculation methodology of estimating risk for individual contaminants, conversion of the annual dose level of 500 mR/yr recommended by FDOH to a corresponding risk and Ra^{226} soil criterion would result in a risk level of 7×10^{-3} and 85 pCi/g, respectively.

According to ATSDR, a 100 mRem/yr dose level would correspond to a Ra^{226} soil cleanup criterion of 0.7 pCi/g, which is lower than EPA's ARAR of 5 pCi/g. However, ATSDR's methodology incorporates risks to human health from radon gas exposure along with the risk from gamma radiation exposure. If the risk calculation was made using the same methodology as EPA's, ATSDR's 100 mR/yr criterion would correspond to a Ra^{226} soil concentration of about 17 pCi/g.

FDOH has indicated that it supports a dose-based approach (i.e., mRem/yr) and the guidelines established by the NCRP. FDOH has referenced the NCRP in the development of its recommendation of a threshold of 500 mRem/yr before any remedial response actions would be required. FDOH referenced the NCRP guidelines given that the State does not have regulations designed to address potential risks to human health from exposure to TENORM. Therefore, based on a review of applicable federal and state regulations, the most widely applied and appropriate criterion is the 5 pCi/g above background for Ra^{226} in soil. This is the same criterion established by OSWER Directive No. 9200.4-25. It is protective of human health and the environment and has been applied consistently as an ARAR by EPA in the cleanup of radium-contaminated sites under Superfund over the past 10 years. ATSDR has indicated that, if requested, the Agency would likely conclude that the 5 pCi/g criterion for radium in soil is protective of human health.

A dilemma exists, however, with respect to the need to balance costs with the reduction in risks and the balancing of other socio-economic factors. Large areas currently in residential use, or that could be placed into residential use in the future, are likely contaminated above the 5 pCi/g threshold, and may warrant cleanup at a cost of hundreds of millions of dollars. However, current background levels of Ra^{226} for unmined lands in the "Phosphate Belt" (approximately 1 pCi/g) corresponds to a risk level that is approximately equivalent to the upper end of the CERCLA risk range of 1×10^{-4}. Correspondingly, the highest levels of Ra^{226} observed thus far in soil are in the range of 10^{-3} to 10^{-2} excess risk above background. Cleanup of these areas would only result in a one to two order of magnitude reduction in risk. The identification of residential areas as "Superfund Sites" warranting cleanup under CERCLA would likely create significant socio-economic issues, including the deminishment of property values and negative public impression as many residents would be part of a "Superfund Site" with radiation contamination.

Many discussions have occurred among EPA, ATSDR, and the State of Florida in an effort to develop an approach that balances the protection of human health with reduction in risk, costs, and socio-economic impacts. While many alternatives have been discussed that are based on radiation dose level, these alternatives would not be considered protective, nor compliant with ARARs. One alternative would be to attempt to balance cost and other factors while ensure that the ARARs are met.

5.2 Recommended Next Steps

If a decision is reached to continue with the evaluation of this environmental problem, and it is further decided to proceed with the work to achieve a CERCLA type of repsonse, the work must be protective of human health and compliant with ARARs. The remedy would, therefore, need to reduce risks to 10^{-4} and soil cleanups would incorporate the criterion of 5 pCi/g above background.

Because these would be the minimal requirements for the cleanup of any TENORM-related contamination under CERCLA, it would appear that the only opportunity to balance the work in terms of cost-effectiveness and socio-economic issues would be during the initial characterization and implementation of the work.

Therefore, it is recommended that the UMTRCA criterion of 5 pCi/g above background for Ra^{226} in soil be recognized by EPA as the most appropriate criterion for any CERCLA response action having radiation contamination. Additional resources should then be invested in further exploring alternatives that would help to balance cost and socio-economic issues during the characterization and implementation phase of work.

If a reasonable approach could be developed that would ensure protection of human health and compliance with ARARs, while balancing cost-effectiveness and other socio-economic issues, it is recommended that the project proceed with the formal characterization of the radiation levels in the residential and CERCLIS site areas. This initial characterization would be through the measurement of radiation levels from an aerial platform as discussed in previous briefings on radiation survey methods.